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(54) METHOD OF AUTOMATIC FOLLOW-UP OF THE FOCUSING OF A MICROSCOPE EQUIPPED WITH A TELEVISION CAMERA

(71) We, CARL-ZEISS-STIFTUNG, a Foundation established under the laws of Germany, 7920 Heidenheim (Brenz), Wuerttemberg, Germany trading as CARL ZEISS, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of automatic follow-up of the focusing of a microscope equipped with a television camera, starting from an initial positon.

The focusing of a microscope, that is the focusing of the observed image is commonly effected by manual actuation of the respective adjusting means whereby an adjusting control is carried out visually. Several devices for the automatic focusing of microscopes are known in the prior art. In these devices, via an additional optical path of rays or by means of electrical scanners the distance between microscope objective and object is constantly measured and re-adjusted to a constant value. Devices of the type indicated are expensive and do not always produce the desired result, since the image itself is not used for judging the image-sharpness.

Microscopes are known in the prior art in which the enlarged image of the object is produced on the cathode of a television pickup tube. Then, the microscopic image can be reproduced at any desired position on as many television sets as desired. Here too, focusing is commonly effected manually under visual control.

Also a method of automatic focusing of television microscopes of the type indicated hereinbefore is known in the prior art. In this method an object detail of approximately homogeneous luminance is selected and an electric signal generated whose amplitude is proportional to the length or the area of the selected detail. Focusing of the microscope is then adjusted until the signal amplitude reaches a minimum value.

This method is time consuming since it requires the selection of an object detail of specific nature which cannot be found offhand in every object image.

A preferred field of application of the television-coupled microscope is in automatic image analysis in which characterizing data such as the number of particles in the image, their longitudinal or surface distribution are obtained from the video signal gained during television scanning. This image analysis is effected automatically and rapidly.

If it is the aim to analyze a larger object, this object is moved in steps, and during each step the resulting image portion is analyzed electronically. Thus, the object is finally combined from a plurality of image portions. During object movement it is not certain that the optimum focusing condition, adjusted prior to movement initiation, is maintained. Should it be intended in case of deivations to reset the focusing condition under visual control to the optimum value, this complicated procedure would substantially retard the otherwise extremely rapidly progressing analysis.

It is therefore an object of this invention to cause the focusing of a microscope equipped with a television camera starting from an initial adjusted focusing condition to follow up automatically and rapidly and in this connection apply an objective adjustment criterion. According to the invention this object is attained by providing that the drive serving for focusing of the microscope is first operated in a fixed direction by a preset amount and thereafter in the opposite direction, that a higher frequency band of the video signal is rectified and the maximum of this rectified signal is established during said travel in the opposite direction, and that after a specific time interval after the maximum has been established, said drive is reversed in its rotary direction and is switched off after a further. time interval, which is equal to the aforesaid time interval.

The automatic focusing hereinbefore described can be initiated by the observer at desired instants resulting from visual observation, however, it is also possible,

for instance, when scanning a larger object to initiate focusing automatically after preset time intervals.

In the novel method the maximum contrast in the image content and therewith the maximum of the proportion of high frequencies in the video signal is selected as a criterion for focusing. This criterion always leads to an optimum focusing which is only influenced by the image content itself.

The adjustment criterion applied in the novel method does not permit to forecast in what direction the focusing drive must be moved in order to obtain the desired focusing. For this reason, first the focusing drive is quickly moved in a fixed direction by a preset amount and thereafter is moved more slowly in the opposite direction. During this travel in the opposite direction the optimum of the focusing is obtained, however, the maximum of the rectified higher frequency video signal band is only recognized after the optimum adjustment has already been passed through. For this reason the method is carried out such that when the maximum has been established said travel in the opposite direction is still continued during a specific time interval, that thereafter the travel direction is reversed and a travel is effected at the same speed during the same time interval. By this, the optimum focusing is obtained with great accuracy.

In order to avoid a misadjustment, prior to rectification of the higher frequency video signal band the synchronous pulses present in the latter are blanked.

It has shown to be advantageous to filter a frequency band whose resonant frequency is above 1 megacycle and whose band width is, for instance, 200 kilocycles, out of the video signal of the television pickup tube and subsequently rectify the same.

The novel adjusting method is expediently carried out such that in the case when a maximum of the higher frequency video signal is not established during said travel the focusing drive is automatically returned to the initial position.

The movement of the focusing drive can be effected by motor, however, it is also possible and advantageous too in case of restriction to small adjusting movements to carry out adjustment of the focal plane of the microscope via piezo-electrical elements which move the microscope objective.

This invention will now be described more fully by reference to the Figs. 1—3 of the accompanying drawings, in which:

Fig. 1 illustrates an embodiment of an arrangement operating in accordance with the method of the invention;

Fig. 2 illustrates two adjusting movements plotted over the time axis, carried out by the arrangement according to Fig. 1;

Fig. 3 illustrates an object during scanning.

In Fig. 1 reference numeral 1 designates a microscope of conventional construction used to observe an object referenced 2. The microscope 1 is equipped with a television camera 3 which serves to scan the microscopically enlarged image of the object 2. Reference numeral 4 designates the focusing drive of the microscope by means of which the specimen stage 5 is moved in a vertical direction until a sharp object image appears on the monitor 6 connected with the television camera 3.

The video signal generated by the television camera 3 is supplied to an amplifier 7 and from these passes to a frequency filter 8 which, for instance, filters out a frequency band of a band width of 200 kilocycles and of a resonant frequency above 1 megacycle and supplies it to a switch element 9. From there the video signal lying in the filtered-out frequency band passes to a rectifier 10 and the rectified voltage is supplied to an arrangement 11 for maximum signal recognition. Controlled by the video signal, a blanking pulse is generated as at 12, which blanks the synchronous pulse in the video signal in the switch element 9 so that only the video signal corresponding to the actual image content is supplied to the rectifier 10.

The arrangement 11 recognizes the maximum of the rectified video signal and when the maximum is established it supplies a stop signal for program control 13. Via the motor control 14 the latter is connected with a drive motor 15 which, as shown by the dotted line, serves for driving the focusing arrangement 4 of the microscope 1. A switch 16 is used to actuate the program control 13.

In Fig. 3 a larger object 17 is illustrated which is positioned on the stage 5 of the microscope 1. For analyzing the object 17 the stage 5 is moved in such a manner that scanning of the object 17 is effected in the direction of the arrows 18, 19. In this manner the total area of the object 17 is combined from small partial areas 20. Each individual partial area is indicated on the monitor 6 and analyzed by means of an analyzer circuit known per se and not illustrated in Fig. 1.

During scanning of the object 17 it is not possible to ensure that the focusing condition adjusted manually prior to the beginning of the scanning action is maintained. For elucidation the curve 21 illustrated in Fig. 2 is used. The latter illustrates the time history of optimum focusing which is characterized in the novel method by the contrast in the image.

The initial focusing condition adjusted

prior to start of the scanning is referenced 22 in Fig. 2. As can be seen, at the instant t_1 the actual focusing condition 21 deviates so much from the adjusted focusing condition 22 that the object image is no longer sufficiently focused.

Now, at the instant t_1 the observer presses the switch 16. By the program control 13 via the motor 15 the focusing drive 4 of the microscope 1 is first quicky moved in a fixed direction along the curve branch 23 by a preset amount. After a preset time, the rotary direction of the motor 15 is then reversed via the control 13 and at the same time its rotational speed is reduced. Therewith the actual searching travel referenced 24 in Fig. 2 is started. During this searching travel the optimum focusing condition is reached as at 25. In this condition the filtered-out higher frequency video signal rectified as at 10 has a maximum which is recognized by the arrangement 11. As soon as this maximum is recognized, the arrangement 11 supplies a stop signal to the program control 13. After having received this stop signal the latter still continues the searching travel 24 during a specific time interval and then again reverses the rotary direction of the motor 15. Now, the latter returns along the curve branch 26 exactly to the maximum position 25. The focussing condition now adjusted is referenced 27 in Fig. 2.

If, during further scanning of the object 17 the focusing condition referenced 27 again deviates from the actual optimum focusing condition 21 as is, for instance, the case at the instant t_2, a further automatic follow-up is initiated by actuation of the switch 16 as is shown in Fig. 2. The focsuing condition obtained by this second follow-up is referenced 28.

The example described by means of the Figures 2 and 3 does not outline the full applicability of the novel method. In particular, it is possible to first manually focus a television microscope which adjustment need not be optimal. By actuation of the switch 19 optimum focusing is then automatically obtained in the described manner.

It is expedient to so devise the method that in the case of non-established maximum of the higher frequency video signal the focusing drive 4 is automatically returned to the initial position value which in the embodiment of Fig. 2 would correspond to the value 22 at the instant t_1.

WHAT WE CLAIM IS:—

1. A method of automatic follow-up of the focusing of a microscope equipped with a television camera, characterized in that the drive serving for focusing of the microscope is first operated in a fixed direction by a present amount and thereafter in the opposite direction, that a higher frequency band of the video signal is rectified and the maximum of this rectified signal is established during said travel in the opposite direction, and that after a specific time interval after the maximum has been established, said drive is reversed in its rotary direction and is switched off after a further time interval, which is equal to the aforesaid time interval.

2. A method as claimed in the Claim 1, characterized in that prior to rectification of the higher frequency viedo signal band the synchronous pulses present in the latter are blanked.

3. A method as claimed in the Claim 1, characterized in that in the case of a maximum of the higher frequency video signal band not being established the focusing drive is automatically returned to the initial position value.

4. A method as claimed in the Claims 1 to 3, characterized in that a frequency band whose resonant frequency is above 1 megacycle and whose band width is 200 kilocycles is filtered out of the video signal and is rectified.

5. A method as claimed in the Claim 1, characterized in that adjustment of the focal plane of the microscope is carried out via piezo-electrical elements which adjust the microscope objective.

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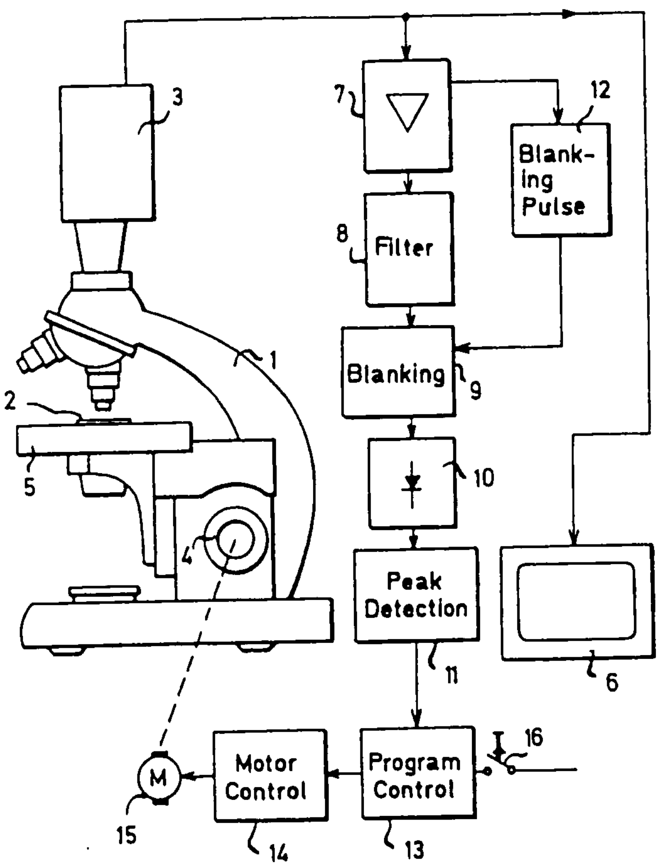
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Fig.1

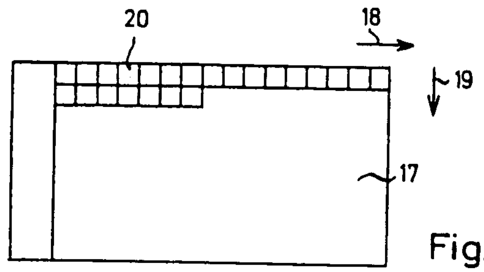

Fig.3

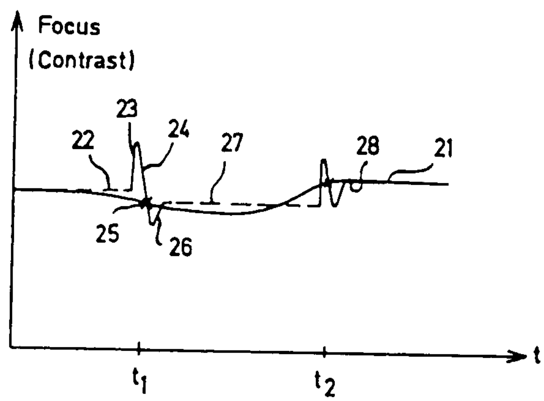

Fig.2